Experiential-Adaptative Hybrid Model for Hospitality Based on CNN Neural Networks, Case-Based Reasoning (CBR) and 360° VR

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***Abstract*—In this work, an Experiential-Adaptive Hybrid model for hospitality based on Convolutional Neural Networks (CNN) neural networks, Case-Based Reasoning (CBR) and 360° VR, is proposed for generating experiences in hotel marketing and promotion activities. The model is based on CBR, which considers user profiles and immersive 360° videos. The work also improves and automates the video tagging process, using CNN, transitioning from a manual to an automated process. The 360° Virtual Reality (VR) experiences can elicit responses across behavioral, affective, cognitive, and attitudinal dimensions; therefore, they are evaluated within an immersive 360° VR environment. To validate the results obtained from this approach, a quasi-experimental study was conducted using various visual experiences, including surrounding landscapes, facilities, environments, and services of a boutique hotel. This study employed a random sample of young participants. This work aims to contribute to the use of 360° VR videos for visualizing the characteristics, environments, and services of hotels in a tour tailored to user profiles, with the goal of evaluating attitudinal and behavioral, cognitive and affective responses as well, and the potential influence on booking and purchase intentions. Conclusions and recommendations for future research are established.**

***Keywords*—experiential marketing, sensorial marketing, adaptative hospitality marketing system, 360° Virtual Reality (VR) video, case base reasoning in marketing**

I. Introduction

Virtual tours in tourist centers, museums, factories, manufacturing industries, laboratories, and hotels—within the context of tourism, education, hospitality, and industrial activities—can be enhanced through Immersive Virtual Reality (IVR), which has the potential to influence users and organizational marketing strategies, as well as attract new clients. 360° VR employs a range of technologies to foster positive user feedback by offering a first-person perspective through a Head-Mounted Display (HMD) [1]. Content created using these technologies generates interest by allowing users to actively engage in the experience, as noted in recent studies, since the visual environments are based on real-world photographs and videos [2]. According to Rahaman *et al*. [3], IVR experiences can be created using 360° videos, which significantly influence the user's sense of presence and entertainment.

Ongoing technological advancements in capturing real-life scenes have made 360° panoramic experiences with immersive and interactive tours possible [3]. Providing virtual experiences can increase user confidence by allowing them to explore the places and services they plan to visit [4, 5]. Recent research shows that immersive technologies significantly affect behavioral responses in destination marketing [6], and that virtual reality has a substantial influence on destination image and visit intentions [7].

However, current virtual tours offer generic experiences that do not take individual user preferences into account, resulting in low levels of personalization and limited engagement. The lack of adaptive systems that integrate prior knowledge of hotel experiences with users' specific preferences represents a significant gap in the current literature. This limitation is particularly relevant in the hotel sector, where service personalization is key to customer satisfaction and competitive differentiation.

Pirker and Dengel [8] point out that 360° VR also presents certain drawbacks, mainly related to cognitive factors such as the cognitive load generated by the learning and integration processes involved in immersive experiences.

This study proposes a software architecture model that uses Case-Based Reasoning (CBR) to deliver personalised virtual tours in a 360° VR environment, tailored to individual user profiles. This allows users to have direct experience of the hotel facilities. This approach incorporates both explicit and tacit knowledge about hotel services and guest experiences, requiring prior registration of user profiles and preferences to enable customized experiences.

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The aim of the model is to create virtual tours of hotel environments, including their services and surroundings, while also allowing for the exploration of the relatively understudied impact on users' affective, cognitive, attitudinal, and behavioral dimensions. These aspects are linked to adaptive tours based on user profiles, in line with findings by Slevitch, *et al*. [9], who reported significant differences between visual conditions produced with 2D and 3D technologies.

The proposal also includes the use of Convolutional Neural Networks (CNN) neural networks for the labeling process of segmented videos used in the composition of virtual tours, as well as the incorporation of new valid cases into the case base through a CBR mechanism integrated with fuzzy logic. This is necessary since not all user-submitted cases can be considered valid for future queries within the application.

This article is organized as follows: Section II reviews and analyses the state of the art. Section III introduces the software architecture model based on CBR, including the automated labeling functionality implemented through a CNN neural network. The methodology used in the study is detailed in Section IV. Section V presents the test results and their discussion. Section VI outlines the conclusions, and Section VII addresses the limitations and directions for future research.

II. Literature Review

A. Marketing and Experiences

To model the developed system, it was necessary to review various sources of prior experience, including Intelligent Tutoring Systems (ITS) [10], Pedagogical Agents (PA) [11], and particularly Adaptive e-Learning systems [12, 13]. The features and attributes of these systems, related to adaptive functionalities and parameters, can support the delivery of virtual marketing experiences tailored to hotel guests' profiles, characteristics, and expectations, enhancing their exploration, learning, and cognitive engagement. According to Grubišić *et al*. [14], this perspective helps adapt the interaction process with virtual objects, which should be dynamically presented based on individual profiles. Customer characteristics play a key role in decision-making and are essential for developing an adaptive marketing system. This study identifies content adaptability attributes and individual interest areas to offer improved visual experiences. By applying Case-Based Reasoning (CBR) in combination with fuzzy logic, the system can assess new cases to determine whether they should be added to the CBR case base, helping to refine the model's search capabilities. To guide the development of the hybrid fuzzy-CBR system, previous studies that applied fuzzy logic in different stages of the CBR life cycle were reviewed [15].

B. Marketing Strategies for Hotels

Hotel occupancy rates are categorized as follows:

1) Marketing strategies

Some strategies are aimed at:

- Product strategy: Consisting of renting hotel rooms, bungalows, meeting rooms, and other facilities.
- Advertising strategy: Utilizes various channels such as websites, brochures, social media, digital marketing, television, and others.
- Location strategy: Emphasizes strategic locations such as the Amazon rainforest, urban, rural, and commercial areas, seaside resorts, artisan markets, historical monuments, casinos, entertainment centers, and more.
- Service strategy: Targeted at three-star hotels and above, ensuring appropriate services, friendly and attentive staff, and well-trained personnel.
- Physical environment: Includes modern buildings, interior designs, and well-maintained renovated historical buildings. Various environments may feature urban, rural, archaeological, Amazonian, and beachfront landscapes, among others.

Traditional strategies are used in hotel management.

2) Experiential–sensorial marketing strategies

Experience generated by experiential marketing are designed to engage multiple senses, promoting experimentation and action. This requires the development of an environment focused on facilitating interactions to enhance the presentation of attributes such as price, quality, and product or service promotion [16]. Contributions in service and marketing actions must be identified. Services have characteristic attributes for their evaluation, taking into account the stakeholders: company, customers, and suppliers. Experiential marketing aims to elicit sensory, emotional, cognitive, and behavioral responses in consumers, drawing on dimensions such as Sense, Feel, Think, Act, and Relate, originally proposed by Schmitt and empirically validated in hotel settings [17]. Recent literature confirms that these experiential dimensions have a positive impact on guest satisfaction, brand trust, and behavioral intentions in tourism and hospitality contexts [18].

Subsequently, Pine and Gilmore [19] suggest adapting the scale:

- Education and prior knowledge of the tourist.
- Aesthetics and environmental quality.
- Entertainment.
- Tourist escapism requirements.

Experience-based marketing seeks to satisfy users' needs for lived experiences which are categorized as sensory, emotional, cognitive, and action-based experiences [20]. Hotel organizations must develop strategies to enhance customer satisfaction and improve the occupancy rate of available capacity [1]. To achieve this, they propose:

- Sensory experience: This can be achieved by promoting local culture and traditions, such as regional music, traditional dances, photographs of tourist destinations, and community crafts placed in strategic locations. An approach to the sense of taste would involve offering traditional dishes from the local gastronomy. By engaging multiple senses, the goal is to create unforgettable impressions, encouraging reservations and future visits.

- Feel the experience: The perception of reputation and service quality depends on the excellence of service delivery, ease and convenience in management procedures, pleasant services provided with kindness, and a reliable and safe environment.
- Think about the experience: Offering consumers surprises or gifts related to birthdays, corporate anniversaries, or significant dates, as well as commemorative items for special festivities.
- Act on the experience: Focusing on elements related to the hotel's identity, interior attractions, facilities and decoration, culinary offerings, staff hospitality, and background music—all with the aim of leaving positive and lasting memories in the consumer's mind.
- Storytelling and story-doing experiences: The combination of the above experiences can add value to consumer satisfaction by engaging five sensory experiences, behavioural experiences, knowledge-based experiences, and physical experiences.

The concept of Customer Brand Engagement (CBE) involves behavioral, affective, and cognitive dimensions [21]. Affective engagement entails establishing a positive relationship with customers by considering key characteristics, benefits, or opportunities to create pleasant and memorable experiences, with a focus on improving perceptions and preferences related to the brand. Behavioral engagement is achieved by encouraging active participation, strengthening the desire to purchase or use a brand's product or service. Finally, engagement can trigger a conscious state of attention, which may influence brand awareness, absorption, and retention.

When the CBE environment is enriched, it can foster immersive interactivity within the social interaction dimension, contributing to the capture of a brand's social engagement, which involves sharing the brand, knowledge, experiences, and support [22]. Experiences in the context of 360° VR include the social dimension and the mental motivation that arises from the consumer's affective, cognitive, behavioral, and social responses, all of which are integrated through 360° VR resources.

3) Virtual Reality (VR) in marketing and advertising

Virtual Reality is defined as a simulated image of the real world, artificially created using various technological resources. It generates and projects effects on the user's mind, allowing for sensations that closely resemble real experiences [23]. Gutiérrez *et al*. [24] identify key elements of VR, including simulation, implicit interaction and sensory immersion. Many of these experiences cannot be generated in the real world and can be highly useful in workforce training, education, and marketing, falling within the concepts of "Reification", "Dimension", and "Transduction" [25]. Representations in VR, such as so-called avatars, can contribute to the design of interfaces for interaction with other users or objects in the virtual world [26].

These technologies hold great potential for assisting tourists in discovering destinations and enhancing their experiences across time and space, creating shared value among industry stakeholders [27].

Mobile technologies allow users to engage in both virtual and real-world experiences simultaneously. Recent reviews classify virtual reality into non-immersive, semi-immersive, and fully immersive formats, highlighting their distinct effects on presence, engagement, and marketing effectiveness [28]. Similarly, VR technologies are categorized as non-immersive, fully immersive, and semi-immersive [29]. Head-Mounted Displays (HMDs) are widely used in tourism marketing and virtual tours, as they are considered an effective and cost-efficient solution due to their immersive simulation capabilities and relatively low cost.

Various studies have demonstrated that VR provides marketing specialists with opportunities to create immersive visual experiences for customers, appealing to a sense of personalization, realism, and interactivity. Users can immerse themselves in captivating virtual worlds while simultaneously receiving memorable advertisements [30].

Customers may find that the integration of proposed technologies offers greater added value, as optimal experience can be generated by using both virtual and physical touchpoints. In VR, more dynamic roles in experiences can be implemented by leveraging VR resources, thereby enhancing their perceptions [31].

Various studies on VR have focused on evaluating customers' perceptions of presence and immersion, as well as on narrative transportation and the development of stories that complement these elements [32]. The effects of sensory cues and the visual and aesthetic elements of immersion can generate strong experiential responses [33, 34].

The information that users perceive through AR, VR, and MR technologies can stimulate customers' imagination during, before, and after the purchase process. These technologies provide consumers with omnichannel experiences enhanced through the use of different offline and online touchpoints.

360° VR technologies are used to develop the Adaptive Experiential Marketing Model, enabling interactions that take user profiles and interests into account. This allows for the creation of personalized experiences and virtual tours that showcase the information and offerings of a hotel within a specific environment.

4) 360-degree Virtual Reality (VR) in hotel tourism marketing

With VR resources, real-world content can be visualized, stimulating the senses—particularly vision—through the use of 3D VR and 360° VR technologies. These enable the creation of immersive real-time experiences that closely resemble reality.

Immersive visualizations allow for high levels of control, enabling interactive experiences with greater quality and intensity compared to standard videos. 360° VR generates convincing representations of potential tourist destinations in a way that is closer to reality than conventional videos [35].

5) Case-Based Reasoning (CBR) methodology

Lemnaru *et al.* [36] explains that in CBR, the user submits a query using text or by selecting available options within the application to specify information about the search object, triggering a similarity-based search to retrieve the *k* most relevant cases. In the proposed model, hotel tours featuring various themes and services are offered, and the one that best matches the user's profile and interests is recommended based on the information stored from each interaction.

To retrieve the most relevant case, the system compares the similarity between the target case and each case in the case base. Each attribute of the case is weighted by a factor that reflects its importance in the search. The similarity across all attributes is then calculated to identify the closest matches. Anteneh Alemu *et al.* [37] detail this process. The resulting similarity percentage is used to rank the stored cases, allowing the system to continuously learn and improve over time.

As noted, this type of reasoning is appealing because it can operate effectively with a limited amount of data, requiring only the storage of new cases, unlike neural network-based systems, which depend on large datasets [38]. In this proposal, CBR is activated when a user searches for tours they wish to explore. This increases the likelihood of identifying options that match their needs; therefore, the system must be prepared to handle a wide range of queries due to the diversity of user preferences. The model is shown in Fig. 1.

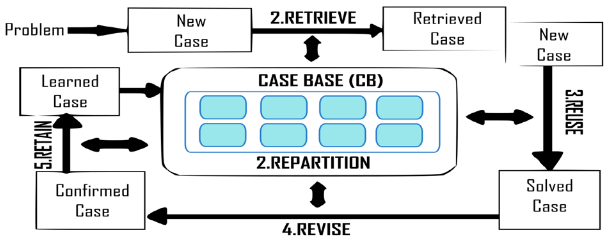

Fig. 1. R4 CBR model.

6) Fuzzy logic

Macías-Bernal *et al.* [39] argue that there is often a reasonable alternative between strict logic and expert opinion, which calls for the development of approximate reasoning models or expert systems grounded in fuzzy set theory, a mathematical approach that seeks to emulate human reasoning.

7) Convolutional Neural Networks (CNN) architecture

A multi-layered CNN architecture includes the input layer, convolutional layers, pooling layers, and fully connected output layers.

- An input image is provided to the CNN through an input layer. The data passed to the convolutional layer are processed using filters that slide over the image to detect specific patterns. For the purpose of reducing data dimensionality, values from a subregion of the image are grouped and replaced with a single value. By using fully connected layers, the patterns detected in previous layers are classified. The final predictions are provided by the CNN, as shown in Fig. 2. CNNs are used for the implementation of computer vision tasks.
- Convolutional layer: It applies filtering operations to input images using filters that slide over the input image, applied to a subregion of the image [40]. These filters analyze specific patterns, such as texture or edges. A small matrix of numbers constitutes the filter, which is multiplied by the pixels within specific windows, and the products are then summed. These filters are used to detect patterns in the input data from which important features are extracted.
- Activation function: A mathematical equation established in the output layers of a neuron, prior to sending outputs to the subsequent layers of the network. It regulates outputs, making it possible for the network to learn more complex patterns [41]. Commonly used functions include Softmax, Sigmoid, Tanh, and ReLU. Each function has its own advantages and characteristics. The selection of an activation function will depend on the problem to be solved and the nature of its data.
- Pooling layer: In CNNs, used to group sets of inputs with similar groupings, typically implemented using pooling algorithms. It can also be applied in unsupervised learning tasks such as image segmentation.
- Fully or densely connected layer: All neurons are connected to the neurons in the previous layer and receive input signals from that layer, producing outputs that are passed to the neurons in the next layer. These layers are used for image classification and natural language processing.
- Overfitting reduction: A technique used to regulate and reduce model complexity so that the model weights do not become too large. The dropout technique in the layers of the neural network is used for this purpose [42]. The goal of optimizing performance is based on the fact that overfitting is a problem in machine learning when the model fits too closely to the training data, potentially leading to poor performance on new, unseen data.

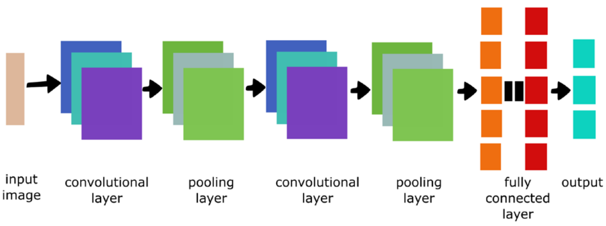

Fig. 2. CNN architecture.

- Transfer learning: A useful process in which knowledge obtained from one task is utilized to improve performance in different tasks. It is a form of machine learning in which the model reuses what it has learned to enhance the performance rate in another task [43].

The transfer learning process is shown in Fig. 3.

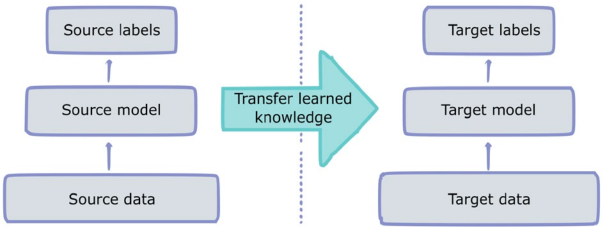

Fig. 3. Transfer learning.

To conclude, this study seeks to understand intrinsic and extrinsic motivations and their influence on customer satisfaction in VR environments, as well as their impact on customers' booking and travel intentions.

The research questions for the development and validation of the obtained results are:

- What method will be used to develop the experiential-sensory software architecture for hospitality using 360° VR, CBR, and CNN Neural networks?
- How to validate the intelligent CBR component?
- How to validate the labelling component, focused from the perspective of CNN neural networks?
- How to compare visualizations of traditional photos and videos with 360° VR in marketing applications, linking with: (1) attitudinal/behavioral responses, (2) affective responses, and (3) cognitive load, taking into consideration the effort required by experiences and tasks using the technology.

III. Materials and Methods

This architecture is designed to create experiences framed within sensory and experiential marketing strategies, generating stimuli with the aim of prompting customers to respond to these stimuli, ultimately leading them to active purchasing behavior after pleasurable experiences [44].

Customers have experiences based on holistic and multidimensional construction processes that involve cognitive, physical affective and emotional responses [45]. The modules of the proposed architecture are shown in Fig. 4.

The implementation was developed using the 4+1 architectural view model, which allows simultaneous multiple views for the description of architectures.

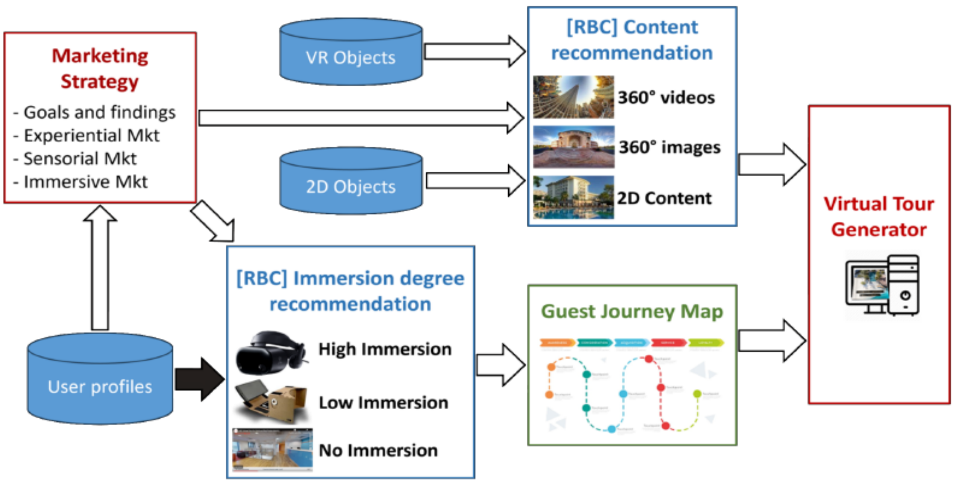

Fig. 4. Software architecture.

A. *Immersive Marketing Strategy*

The establishment and implementation of the required strategy for generating virtual content for different types of experiences, including static images, virtual objects, 360° VR videos, GIFs, and texts, are carried out in this module. The module must incorporate strategies focused on the senses of sight, hearing, and taste, considering the elements discussed in the section on experiential marketing strategies.

B. *Virtual Content Generation*

The establishment of the structure for generating virtual objects, including 360° VR, involves segmenting them and then composing virtual tours tailored to user profiles according to CBR recommendations. It includes the necessary information for access using hot points required to implement dynamic interactions, framed within experiential-sensory marketing strategies.

Additionally, it enables the simulation, testing, and evaluation of virtual content, as well as the storage of resources related to proposed tours for different profiles. It includes parameters for adapting content within the CBR, providing users with tools for exploring and searching for information on hotel offerings, infrastructure, leisure and cultural activities, and the hotel's surroundings.

C. Case-Based Reasoning (CBR) Content Recommendation

A component focused on adaptive logic in the execution of adopted marketing strategies, making navigation and virtual presentation adaptive for viewing hotel services, facilities, and surroundings.

This component, based on CBR, determines the tour routes according to user profiles and the level of immersion of the available devices. Objects are dynamically presented to users based on their requirements, using an interface similar to the one shown in Fig. 5.

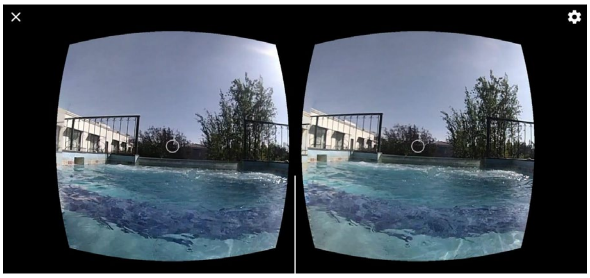

Fig. 5. Virtual tour.

The tours are composed based on the functionality of the video segmentation model, establishing routes according to CBR recommendations. The tours can be enhanced by incorporating objects such as images, videos, and soundtracks, with the aim of focusing on marketing strategies that enable users to explore the available hotel information using hot points.

Each "case" results from a query with descriptors based on attributes such as:

- ID: Identifier for recommended user routes.
- Zone: location, such as city, beach, countryside, Amazon rainforest, etc.
- Purpose: Business trip, vacation, tourism, etc.
- Services: Visualization of images of interest in 360° VR.
- Companions: Whether the user is traveling alone or with others.
- Priority: A characteristic or attribute considered important when choosing a hotel.

Six parameters were established for the search engine, which are similar to those of the CBR mechanism:

- Name of the attribute for performing searches.
- Search attribute value for cases with nearby values.
- Weights for searches, obtained based on average opinions from experts and potential users, as shown in Table I.
- Terms: The method for searching using an attribute, such as greater than, equal to, close to, etc.
- Scales that are mathematical representations, which can be categorized as linear, logarithmic, etc. They establish how to perform searches for differences between new and stored cases.
- Search options: Method for returning results, with default values set to the closest matches that should be retrieved.

TABLE I. ATTRIBUTE TABLE

Attribute	Weight (%)
Zone	15
Motive	24
Services	17
Company	20
Priority	24
Total	100

The search results are classified by prioritizing cases very close to the baseline. The cases can be visualized as recommendations through immersive interfaces, which take into account the preferences of the users who will decide the route to follow, considering the search results, and the new case will be stored in the case base. The objective is to expand the case base record, allowing future searches to be optimized by returning cases that are more closely aligned with the user's preferences.

It is worth noting that for the purposes of this study, approval was requested from the Institutional Research Ethics Committee, which concluded that "the study does not violate any ethical principles".

D. Automation of the Labeling Process Using a Image Classification Model Based in Convolutional Neural Networks (CNN)

In a previous study, a prototype was described for the visualization of hotel virtual tours, where manual processes were used to tag 360° VR videos, in which manual processes were carried out to label videos, which involved downloading the videos and converting them to flat format, which is visualized to establish the environment it belongs to, and this is used as the name for its storage [23]. The process took an average time of 2 Minutes per video, which is significant when dealing with videos from various hotels.

The objective of this section of the proposal is to apply Convolutional Neural Networks (CNNs) to automate and optimize the manual process described for labeling 360° VR videos [46], the procedure of which is illustrated in Fig. 6.

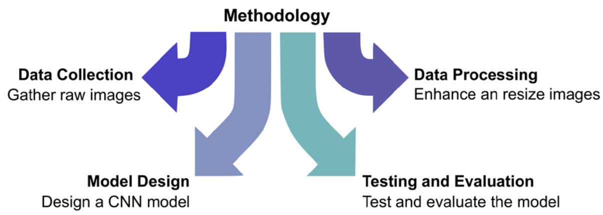

Fig. 6. Proposal flow.

1) Data acquisition

This involves gathering images of hotel environments as data, including rooms, bathrooms, living areas, pools, gardens, patios, and more. A total of 500 images were collected per environment, resulting in a dataset of 2,500 images.

The data obtained were divided, with 80% assigned for training and 20% for testing.

2) Model design

A CNN neuron has a two-dimensional representation in order to align it with the spatial characteristics of the images.

A CNN has an input layer, feature extraction and classification processes, and an output layer. To extract features, hidden layers and pooling layers are included. The architecture can be visualized in Fig. 7.

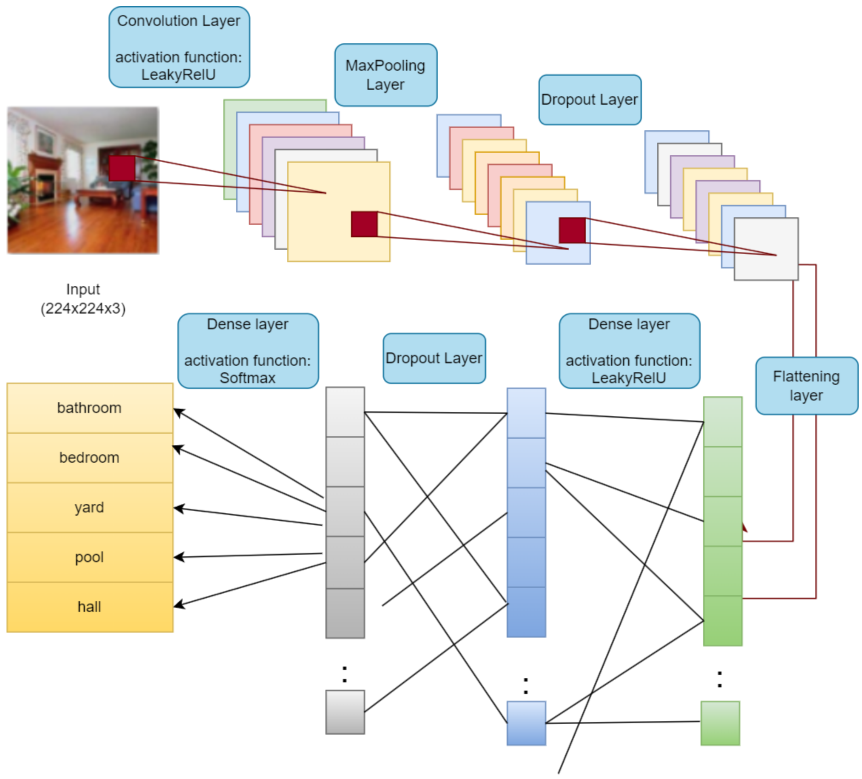

Fig. 7. CNN architecture.

(1) The input image flows through the first convolutional layer with a size of (224, 224, 3).
(2) In this first Convolutional layer (Conv2D), 32 filters of size 3×3 are applied, producing an output tensor of size (224, 224, 32) with the following configuration: (a) Filter: 32; (b) Kernel size: (3, 3); (c) Activation: Linear LeakyReLU function with alpha = 0.1, which allows a small gradient if the unit remains inactive, solving the issue of dead neurons; (d) Padding: The same dimensions are required to preserve the input dimensions; (e) Input mode: Images with 224×224 pixels and 3 color channels (RGB).
(3) The pooling layer employed is MaxPooling2D, which reduces the dimensionality of the feature maps by selecting the maximum value within each 2×2 window, thereby decreasing the tensor size to (112, 112, 32), with the following configuration: (a) Pooling size: (2, 2); (b) Padding: applied to preserve input dimensions.
(4) For regularization, the dropout technique is employed to prevent overfitting, whereby 50% of the neurons are randomly deactivated during the training phase.
(5) For input transformation, a Flatten layer is applied. This layer does not have learning parameters, ensuring that the input shape remains unaltered. All dimensions, except for the first, are collapsed into a single input. The 4D tensor is transformed into a one-dimensional vector with a size of 401,408 (112×112×32).
(6) The dense layer is fully connected, thereby reducing the vector to 32 dimensions. A LeakyReLU activation function is applied to introduce non-linearity after the dense layer. Another Dropout layer is employed, randomly deactivating 50% of the neurons to prevent overfitting.
(7) The dense layer with five units serves as the output layer, with each unit representing a different class.

After designing the model and defining its architecture, the network is trained over 100,366 iterations to improve its accuracy. Once training is completed, the results are stored for use in the labeling process, which is essential for the development of the virtual tour visualization subsystem described in this work.

3) Labeling

In this process, the trained model is used to automate the labeling procedure. The operational flow of this proposal is detailed in Fig. 8. After establishing a folder structure for the proper tagging of videos, the development process continues, following the steps described in the proposed virtual tour subsystem prototype [23].

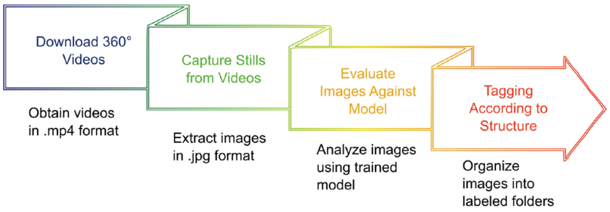

Fig. 8. Labeling flow.

To better interpret the results obtained after training the model, Table II presents the index assigned to each environment category, serving as a reference for reading the confusion matrix.

TABLE II. INDICES BY ENVIRONMENT

Index	Environment
0	Bathroom
1	Bedroom
2	Patio
3	Pool
4	Living room

As shown in Fig. 9, the confusion matrix provides a detailed assessment of classification accuracy. According to the matrix, the environment with the highest accuracy was the patio, with 212 correct predictions and only three misclassifications, one each incorrectly labelled as bedroom, pool, and living room. In contrast, the living room had the lowest accuracy, with 145 correct predictions and several misclassifications as bathroom, bedroom, and patio (9, 26, and 5 errors, respectively). This evaluation conducted using the model. Evaluate function reported a loss of 0.2654 and an accuracy of 91.60%. The training process consisted of 200 iterations and reached an accuracy of 95.09%, as described in [46].

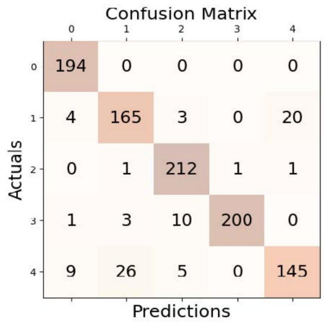

Fig. 9. Confusion matrix.

E. End User Module

Focused on the resources and devices available for implementing marketing strategies, this approach aims to determine the level of immersion in the user experience. The development of the system requires the use of techniques such as Journey Maps, a human-centered design method that visualizes the actions, thoughts, feelings, and experiences of guests. The coding is quantitatively guided, as it divides the guest's "journey" into steps and narrative concepts. Short audiovisuals are used to capture the viewer's attention, delivering information quickly and clearly. In this way, it is possible to support the decision-making process of potential guests by taking emotions and feelings into account, thereby achieving alignment with the experiential and sensory approach of this proposal.

This original, intelligent, and adaptive model integrates different elements of experiential marketing, AI approaches, and immersive VR and 360° VR resources. These elements were incorporated into the proposed software architecture, aiming to support the promotion of hotel facilities, services, and environments.

IV. RESULTS

The methodology for developing and validating the model is as follows:

A. Development of the Model

Stages:

(1) Establish requirements and gather the necessary information based on user experiences.
(2) Map guest journeys for analysis by experts in marketing and management.
(3) Record 360° of images and videos of the hotel, its surroundings, and selected media such as videos.
(4) Create and design user interface systems prototypes for immersion.
(5) Implementation of the application for immersive visualization with HMD using Unity.
(6) Implement a CBR engine and a REST API.
(7) of a CNN-based classification model to automate the labeling process.
(8) Conduct functional, validation, and effectiveness testing of the model.

B. Case-Based Reasoning (CBR) Engine

The operation of the CBR Engine begins by generating a new journey, which corresponds to a recommendation obtained from the CBR search. The input data used includes the attributes: destination area, purpose of the trip, service requirements, companions, and search prioritization. The CBR defines the terms, scales, and weightings for searching and recommending itineraries.

Once the evaluations are completed, a list of cases is returned, ordered by the degree of similarity. Identical cases are removed to avoid duplication in the results, and the obtained information is utilized by the CBR. The web server maintains a list of itinerary identifiers to retrieve the information displayed to users.

A case is considered aligned with the user's interests if the user chooses a route recommended by the model. The search parameters and the selected routes will be stored as a new case in the Case Base, allowing it to be used in future searches, which will help optimize the accuracy of subsequent recommendations.

C. Methodology for Validating the Effectiveness of the Model

The study is exploratory and descriptive, employing an experimental, cross-sectional design with a quantitative approach. For all hypothesis tests conducted in this study, a significance level of $\alpha = 0.05$ ($p < 0.05$) was established, considering this threshold as statistically significant for rejecting the null hypothesis. For the analysis of affective responses, a Bonferroni correction was applied due to multiple comparisons, adjusting the significance level to $\alpha = 0.05 / 18 = 0.0028$.

Several questionnaires were adapted: attitude-related items [47, 48], affective measures [49], and cognitive load measures [33]. To assess cognitive load, the NASA-Task Load Index (NASA-TLX) was used. A random sampling approach was employed, with 203 questionnaires administered to a young population. Data processing was conducted using the SPSS software package.

Following the approach, for the validation of the CNN classification model used in the automation of the labeling process, data were collected from images of common hotel environments [46]. The data were compiled from various internet sites containing specialized datasets of hotel environment images. A total of 500 images per environment were collected, forming a complete dataset of 2,500 images. The dataset was randomly divided into two subsets: 80% for training (n = 2,000 images) and 20% for final testing (n = 500 images).

A boutique hotel in Arequipa, Peru, was used to conduct the study, employing images and videos of the hotel's facilities, rooms, services, and exterior environment in VR-HMD, combined with a smartphone for immersive 360° VR testing. Participants in the VR group received instructions on how to use the device and provided verbal consent for the use of their images for study documentation purposes.

The study was carried out in different locations and environments with participants engaging in experiences lasting an average of five minutes. During these sessions, they were asked to imagine a hotel selection scenario, considering their motivations. Concluded the experience, participants answered a Google Forms questionnaire designed to assess cognitive, affective, behavioral and attitudinal responses, including demographic information as well. The test lasted for one month. A review of literature related to consumer behavior established that affective, cognitive, and attitudinal responses are crucial for comprehension consumption predicting user decision-making and habits and behavior.

For the validation of the architecture, the following questions are established:

- Cognitive load, to assess the effort associated with using the technology and the tasks performed during the experience?
- Affective responses?
- Behavioral/attitudinal responses?

Immersive 360° VR experiences can trigger responses across multiple dimensions, including attitudinal, cognitive, affective and behavioral.

1) Cognitive response—CLT

This model incorporates the limited attention capacity proposal, which provides a framework for understanding 360° VR visualizations. 360° VR images may trigger greater cognitive and perceptual loads compared to 2D images on websites, leading to the following hypotheses:

- Hypothesis 1a: Visualizations in 360° VR, compared to 2D images of similar hotel environments presented on websites, trigger higher cognitive loads.
- Hypothesis 1b: Visualizations in 360° VR, compared to 2D images of similar hotel environments presented on websites, do not trigger higher cognitive loads.

For the test, the NASA-TLX instrument was used. The components evaluated were: stress, irritation, insecurity, discouragement, and discomfort during the task. The statistical procedure was based on:

- Normality test: Shapiro-Wilk;
- Homogeneity of variances test: Levene's test;
- If data were normally distributed: Independent t-test;
- If data were not normally distributed: Mann-Whitney U test;
- Significance level: $\alpha = 0.05$;
- Effect size: Cohen's d.

According to the results shown in Fig. 10, Hypothesis 1b was accepted. This is interpreted as evidence of facilitated information processing in VR. With regard to statistical significance, no specific p-value was reported.

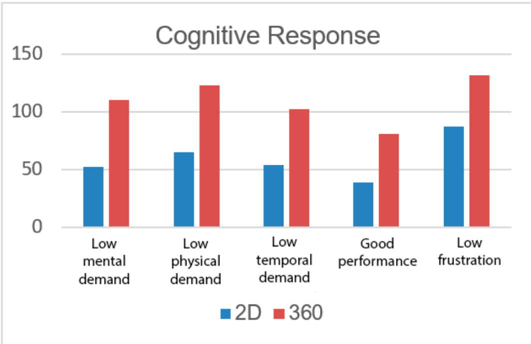

Fig. 10. Cognitive response results.

2) Affective response

Various studies indicate that VR elicits distinct emotional attitudes and physiological reactions, such as increased heart rate, galvanic skin responses, and elevated blood pressure. Immersive VR can also stimulate the senses and evoke intense affective emotions compared to traditional images. Furthermore, VR may generate affective responses such as excitement, feelings of frustration, and pleasure. Therefore, it can be inferred that 360° VR may provoke more intense affective responses when compared to 2D images on websites.

The proposed hypotheses are:

- Hypothesis 2a: Visualizations using 360° VR do not generate affective responses compared to visualizations of similar scenes with images presented on hotel websites.
- Hypothesis 2b: Visualizations using 360° VR generate affective responses compared to visualizations of similar scenes with images presented on hotel websites.

In this case, the instrument used was the PAD model (Pleasure, Arousal, Dominance), which applies an 18-item bipolar scale. The statistical tests employed were as follows:

- Multivariate Analysis of Variance (MANOVA) to assess overall differences in PAD dimensions;
- Independent t-tests for each bipolar item;
- Bonferroni correction: adusted $\alpha = 0.05 / 18 = 0.0028$;
- Subgroup analysis by gender;
- Effect size calculation (partial eta squared).

Based on the results shown in Fig. 11, Hypothesis 2b was accepted. A significant difference of 17% was found among female participants. On the "lively-embarrassed" scale, the VR 360° condition scored -2.1% compared to the 2D condition. On the "relaxed-tense" scale, VR 360° scored -9.4% compared to 2D. This is interpreted as more intense emotional responses in the VR 360° condition.

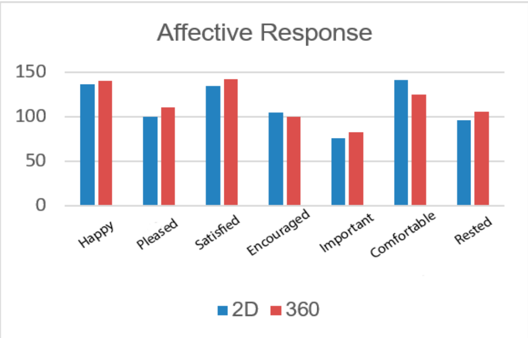

Fig. 11. Affective response results.

3) Attitudinal and behavioral responses

The influence of 360° VR videos on customer behavior and attitudes is possible, and further research is needed in the hospitality and tourism industries, as knowledge in this area remains limited. Therefore, the following hypotheses are proposed:

- Hypothesis 3a: 360° VR visualizations do not elicit positive attitudes compared to visualizations of similar scenes and images on hotel websites.
- Hypothesis 3b: 360° VR visualizations elicit positive attitudes compared to visualizations of similar scenes and images on hotel websites.

The instrument used for measurement was the adapted Attitudes Toward Hotels Scale. The components evaluated were booking intention, expected satisfaction, and price alignment.

The statistical tests used were as follows:

- Reliability analysis (Cronbach's α);
- Normality test;
- Independent t-test for attitudinal scores;
- Significance level: $\alpha = 0.05$;
- Confidence interval: 95%.

According to the results shown in Fig. 12, Hypothesis 3a was accepted. Among the specific differences observed, participants in the 2D condition felt 29% more positive about staying at the hotel.

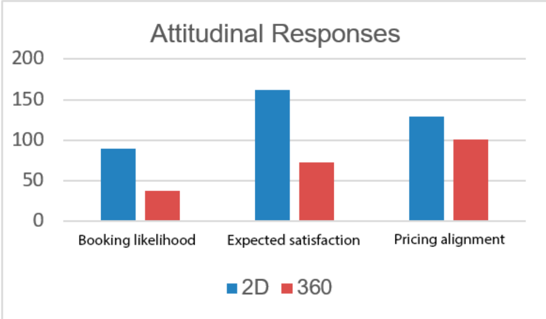

Fig. 12. Attitudinal response results.

- Hypothesis 4a: 360° VR visualizations do not elicit behavioral attitudes compared to visualizations of similar scenes and images on hotel websites.
- Hypothesis 4b: 360° VR visualizations elicit behavioral attitudes compared to visualizations of similar scenes and images on hotel websites.

The instrument used was the 7-item scale for measuring behavioral intentions. The components evaluated were booking intention and likelihood of making positive statements about the hotel. The statistical tests used in this case were:

- Reliability analysis of the scale (Cronbach's α).
- Normality test: Shapiro-Wilk.
- Independent t-test for behavioral intention scores.
- Logistic regression analysis to assess booking probability.
- Significance level: $\alpha = 0.05$.

According to the results obtained, Hypothesis 4a was accepted. Regarding specific differences, it was found that participants in the 2D condition showed a 25.9% higher probability of booking the hotel.

To validate the study, the Pleasure, Arousal, and Dominance (PAD) model [49] and its scale were used, which can also be applied to evaluate physical environments. A statement such as: "After viewing the hotel images, I feel…" introduces the scale-based assessment, followed by 18 bipolar items:

- Adjective pairs to evaluate pleasure: dissatisfied–satisfied, depressed–happy, unhappy–happy, annoyed–content, hopeless–hopeful, bored–relaxed.
- Adjective pairs to evaluate arousal: relaxed–stimulated, excited–calm, drowsy–alert, placid–frantic, nervous–serene, thrilled–unmoved.
- Adjective pairs to evaluate dominance: influenced–influential, controlled–controlling, submissive–dominant, insignificant–important, restricted–unrestricted.

An adapted seven-item scale was used to assess behavioral intentions toward hotels [48], which includes the following questions:

(1) Would you book the hotel you viewed?
(2) How satisfied would you feel if you decided to stay at this hotel?
(3) Are the hotel's prices within the range of your expectations?

Behavioral intention is assessed with the following questions:

(1) What is the likelihood of booking a hotel in this category?

(2) What is the likelihood of expressing positive statements about the hotel?

The validation results for internal consistency using Cronbach's alpha for the questions in both groups were satisfactory and are presented in Table III. A value above 0.8 indicates good consistency and, therefore, the study is considered valid.

TABLE III. VALIDATION RESULTS

Cronbach's alpha	Cronbach's alpha based on standardized elements	Number of elements
0.830	0.832	10

V. DISCUSSION

A. Analysis of the Validation and Effectiveness of the Case-Based Reasoning (CBR) Engine

Validation was carried out using the Case Library Subconfiguration Technique (CLST) test from the CBR [48], aimed at selecting a subset of the case base to evaluate the effectiveness of the retrieval rate. The following parameters were considered:

- The Acceptable Outcome Criterion (AOC) considers the maximum relative error that can be allowed, based on comparison with the gold standard; in this case, a threshold of 15% was set.
- The System Validation Criterion (SVC) refers to the threshold used to determine whether, after evaluating and analyzing the case subset, the case under processing is considered valid. The CBR system treats cases exceeding a 75% threshold as valid. The evaluation yields two possible outcomes: "SUCCESS" for cases that pass the test and "FAILURE" for those that do not.

In the final tests, an acceptance rate of 100% and a retrieval rate of 88% were achieved with a sample of 50 cases. These results allow us to conclude the validity of the CBR system, taking into account the established SVC threshold based on the CLST technique.

Finally, in the tests conducted, a 100% acceptance rate and an 88% retrieval rate were obtained, with a sample of 50 cases. This allows us to conclude that the proposed CBR is valid, considering the SVC threshold established based on the CLST technique.

B. Affective Answers

The two tests showed differences across most items in the affective load dimension. A significant difference of 17% was observed among female participants.

Differences were recorded regarding how stressed, irritated, insecure, discouraged, and annoyed participants felt during the task. The satisfaction and displeasure question showed results 4.9% lower than in Test 1. The 360° VR images received relatively lower scores compared to the 2D images, with a difference of –2.1% on the lively–embarrassed scale. Participants who viewed the 2D images reported higher scores compared to those who viewed the 360° VR images, with a difference of 9.4% on the relaxed-time scale.

C. Attitudinal and Behavioral Responses

There were differences in the behavioral and attitudinal responses between the two tests. In the 2D test, participants reported feeling more positive about staying at the hotel compared to those who viewed the 360° VR, reaching 29%. Participants who viewed the 2D images also showed a higher likelihood of booking the hotel, with a difference of 25.9%.

It can be inferred that there is a stronger preference for booking intentions with 2D visualizations, possibly because the information is more accessible through the hotel's website compared to 360° VR visualizations delivered via hot points. Additionally, the tours suggested by the CBR, based on user profile demands, may have presented partial or incomplete information. Further research is needed to better understand these findings.

The tests assessing the attitude and behavior dimension revealed more positive attitudes and booking intentions in the 2D condition. The lower levels of response observed with 360° VR may be attributed to the video quality, which may have lacked visually appealing and representative features of the hotel facilities. Another possible explanation is that the selected hotel may not have been aligned with the interests of the target audience, considering the social and economic background as well as the age range of the survey participants. Response time may also have played a role, as composing the virtual tour required greater analytical effort, along with the inclusion of objects designed to implement experiential-sensory marketing strategies.

Moreover, the findings of our study regarding affective and attitudinal responses to 360° VR visualizations contrast with previous studies, such as that of Slevitch *et al*. [9], who reported that VR visualizations in hotel contexts do not always lead to higher booking intentions or reduced cognitive load compared to 2D images. In our case, the results indicate a preference for 2D visualizations in terms of attitude and behavior, suggesting that personalization through CBR and the visual quality of the VR environment may be key moderating factors. From a theoretical perspective, this study contributes to the existing body of knowledge by showing how the integration of CBR into adaptive virtual tours can differentially influence affective, cognitive, and attitudinal dimensions, an area still underexplored in the literature.

It is also important to consider possible explanations as to why 360° virtual reality did not yield better attitudinal outcomes or booking intentions compared to 2D images. Recent studies suggest that factors such as cybersickness or visual fatigue can negatively impact the user experience in head-mounted VR environments, particularly when there is a mismatch between visual and vestibular signals or system latency. Additionally, technical familiarity with VR or the lack of prior training may influence users' perceptions of system efficiency and usability, potentially diverting attention away from the content and towards managing the interface. Therefore, these elements may have reduced the effectiveness of 360° VR visualizations especially when compared to 2D, which tends to be more intuitive and familiar for users.

VI. Conclusions

A software architecture model was proposed and developed with an adaptive experiential-sensory marketing approach in a 360° VR environment, based on Case-Based Reasoning (CBR), fuzzy logic, and Convolutional Neural Networks (CNN), to support marketing strategies in the hospitality and tourism sectors.

To validate the effectiveness of the experiences generated by the model, adaptive 360° VR visualizations were evaluated and compared to 2D hotel website visualizations. This comparison was made because image immersion and visualization can elicit experiences across cognitive, affective, and attitudinal dimensions, all of which were assessed in this study.

The results of the study suggest that 360° VR visualizations differ from traditional 2D images on websites, but only in certain dimensions. The cognitive dimension test indicated a low cognitive load, suggesting that information processing was facilitated. The affective dimension test elicited stronger emotional responses, while the attitude and behavioral dimension test revealed positive attitudes and booking intention.

VII. Limitations and Further Research

The data was collected in the city of Arequipa, Peru, involving potential hotel guests as well as undergraduate and postgraduate students from UNSA-Arequipa and undergraduate students from the Universidad Tecnológica del Perú (UTP). It is possible that these participants do not fully replicate real-world conditions.

The scope of the study was limited to certain dimensions, excluding others that may also be relevant.

Future studies should incorporate psychophysiological measures to address potential shortcomings of self-reported data, which may not always be the most accurate method for assessing the effectiveness of the system's application.

The quality of the videos, as well as the response time required for sequence composition and navigation in 360° VR, may have influenced participants' responses and should be taken into consideration in future studies.

Finally, future research should consider the use of VR hardware offering different levels of immersion, along with strategies focused on auditory stimuli.

Informed Consent Statement

Verbal consent was obtained from all subjects involved in the study.

Data Availability Statement

The raw data supporting the conclusions of this article are available from the authors upon reasonable request.

Conflict of Interest

The authors declare that there are no conflicts of interest. The study's funders had no role in the design of the study; in the collection, analysis, and interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

Author Contributions

Conceptualization, L. Alfaro. and S. Quecara.; methodology, S. Quecara and L. Alfaro; software, S. Quecara and L. Alfaro; validation, L. Alfaro and S. Quecara; investigation, L. Alfaro and S. Quecara; data curation, S. Quecara; writing—original draft preparation, L. Alfaro; writing—review and editing, S. Quecara; supervision, L. Alfaro; funding acquisition, L. Alfaro. All authors have read and agreed to the published version of the manuscript.

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